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ABSTRACT

Sixty severely and profoundly deaf children were involved in a study to measure their voluntary pitch control and to investigate the relationship between this skill and the variables of age, sex, hearing loss, habitual pitch, and overall speech intelligibility. Subjects were asked to match three pitch levels and hold them for 10 seconds. Results showed that overall performance was very poor. The older students demonstrated better pitch control than the younger ones, but no evidence was found that any of the other variables affected performance. (KW)

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CONCEPT AND CONTROL OF FUNDAMENTAL VOICE FREQUENCY IN THE DEAF--
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Introduction

The fundamental frequency of voiced sounds (herein referred to as pitch) is an important feature of speech, conveying both linguistic and non-linguistic information. The absence of adequate control of this feature is characteristic of the speech of the deaf and may contribute to low intelligibility.

For the deaf child to learn the production of appropriate pitch patterns in his speech, there are three prerequisites:

- i) knowledge by the teacher of the pitch patterns of normal speech.
- ii) a means of providing the child with information about desired pitch patterns.
- iii) a means of providing the child with information about his own pitch patterns. (i.e. feedback)

Information on normal pitch patterns is available in the literature, but has not generally been applied in education of the deaf. This point has been discussed at some length by Woodward (1967), who has given an outline of normal intonation patterns, based mainly on the work of Pike (1945). She has reported favourably on the success of applying this information to the teaching of speech.

The second and third requirements can be met in three ways: a) through the use of residual hearing and amplification; b) via some visible activity on the part of the teacher, such as raising or lowering the hand or writing on the chalk board; and c) with a speech analyzing device which extracts pitch information and presents it in some suitable form, for example in a visible display.

The success of using auditory channels will clearly depend on the amount of residual hearing, but where possible should be the preferred method of instruction in pitch control. There will remain, however, a percentage of children whose hearing is not adequate for the recognition and control of pitch patterns.

The use of the teacher's hand to indicate high and low pitch has the virtue of simplicity. However, there are two potential drawbacks. One is that the teacher is unlikely to reserve a particular hand position for a particular pitch level. In other words she will be an unreliable indicator. The second is that the child's own efforts must first be processed by the teacher before she can indicate the results. Thus the teacher represents a feedback system with an inherent delay. However, the visible display offers the potential for instantaneous and accurate feedback providing suitable techniques of pitch extraction are used.

There are several descriptions of visible pitch displays in the literature, and also accounts of their use in teaching pitch control. Some of the devices display pitch in one dimension but leave time in its natural form (i.e. time sequences of pitch are converted into time sequences of visible patterns [Coyne, 1938, Plant 1960]). Others display time and pitch in two dimensions, thus converting time sequences of pitch into spatial distributions of visible patterns (Dolansky, 1955, Anderson, 1960, Tjernlund, 1964, Risberg, 1968).

Methods of pitch extraction fall into three categories. First there are those which employ resonant devices, responding selectively when particular frequencies are present. Coyne's device employed tuning forks and used an interesting system of relays to ensure that only the lowest frequency of a complex vibration was indicated. An alternative is to use electronic

circuits to "count" the number of vibration cycles in a given length of time. Both the above methods suffer from the disadvantage that a finite delay is involved before the system can respond to a given frequency. Instantaneous response is provided by systems which measure the duration of each cycle and display its reciprocal. This provides frequency measurement on a cycle to cycle basis, and is the technique employed in the study to be described below.

Reports of the application of visible pitch devices are somewhat disappointing. While it has been shown that deaf children can learn pitch control using visible feedback (Martony, 1966, 1968, Dolansky and others 1965, 1966, 1969, Philips and others, 1968), it has not been demonstrated that this results in an overall improvement in speech intelligibility, nor does the crucial question of the superiority of instrumental over non-instrumental techniques appear to have been researched.

The study to be described was a preliminary to an investigation of the factors involved in teaching pitch control. Its aim was to measure the pitch control of a group of deaf children and to investigate the relationship between this skill and other variables. The study involved the use of instantaneous visible feedback, and it was assumed that a child with an appropriate concept of and control of pitch would quickly grasp the significance of the display and would be able to control the position of the trace.

Aims of the Present Study

1. To investigate the ability of a group of very severely and profoundly deaf children to exercise voluntary pitch control.
2. To determine the relationship between this skill and age, sex, hearing loss, habitual pitch, and overall speech intelligibility.

Subjects

There were sixty experimental subjects, all students at the Clarke School for the Deaf. Twenty subjects were used from each school division as shown in Table 1.

Table 1. Distribution of Experimental Subjects by
School Division and Sex

School Division	Number of Boys	Number of Girls	Age Range in Years
Upper	0	20	14-17
Middle	10	10	9-14
Lower	14	6	7-9

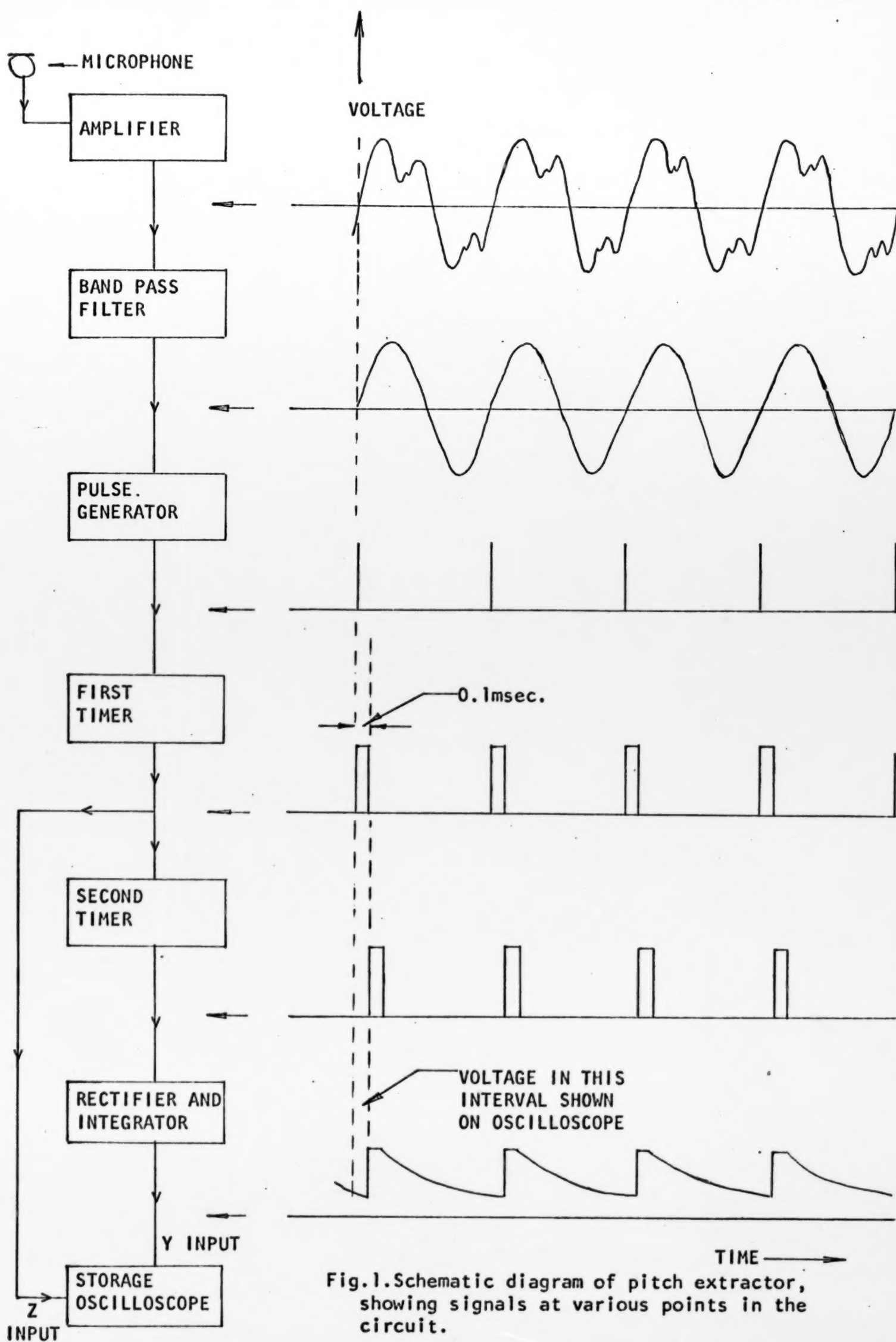
No Upper School boys were used in the study since the target pitches for their voices would have needed to be different from those of the girls. All subjects had hearing losses greater than 80 dB I.S.O. (average of 500, 1000, and 2000 Hz, better ear).

Other Data

Hearing levels for pure tones were taken from the most recent annual audiometric evaluation. Habitual pitch was estimated by having the child say "my name is," and determining by inspection an average level from the resulting trace on the pitch display. Pitch levels were estimated in this way to within 5 Hz. Speech intelligibility scores were previously determined by Magner (1968) and were based on the number of words recognized by a group of naive listeners when the subjects spoke six printed sentences. Speech intelligibility scores were only available for the Middle and Upper School children.

Equipment

The pitch indicator functions as follows. After pick up by a dynamic microphone the speech signal is amplified and passed through a band pass filter. The high pass setting is adjusted to 200 Hz, thus suppressing low frequency noise. The low pass setting is adjusted to 400 Hz, to attenuate second and higher harmonics. The resulting sine wave is then processed by suitable modules of the Grason-Stadler 1200 Series programming equipment. A pulse is generated for each cycle of the sine wave and is increased in duration to



0.1 msec. The trailing edge of this pulse is used to trigger a second pulse of similar duration which charges a capacitor through a diode. Between pulses, the voltage across the capacitor discharges through a resistor to a value which is decided by the time of onset of the next pulse and thus bears a monotonic relationship to periodic time. The voltage across the capacitor is fed to the Y-amplifier of a storage oscilloscope, and the initial 0.1 msec pulse is applied to the Z input for "bright up." The resulting display shows only the voltage across the capacitor at the time of onset of each new pulse. This process is illustrated in Figure 1. A Polaroid camera was used to obtain a permanent record of the subject's performance.

Procedure

Each child was tested individually and was given a short orientation session in which the function of the machine was explained and demonstrated. He was then asked to match three pitch levels and hold them for approximately ten seconds. The target frequencies were:

Low:	200 ± 10 Hz
Medium:	300 ± 15 Hz
High:	400 ± 20 Hz

He then said "my name is" for the indication of habitual pitch.

Evaluation

Performance on the pitch matching task was evaluated on a five-point scale.

Descriptions of the classes are as follows.

Class 4 - could maintain three levels within or close to targets for 6 to 10 seconds.

Class 3 - could maintain three levels but some way from targets.

Class 2 - could maintain levels within or close to two of the targets.

Class 1 - showed some ability to change pitch.

Class 0 - showed no ability to change pitch.

The two experimenters evaluated performance independently by examination of photographs of the oscilloscope tracings, and then resolved or compromised

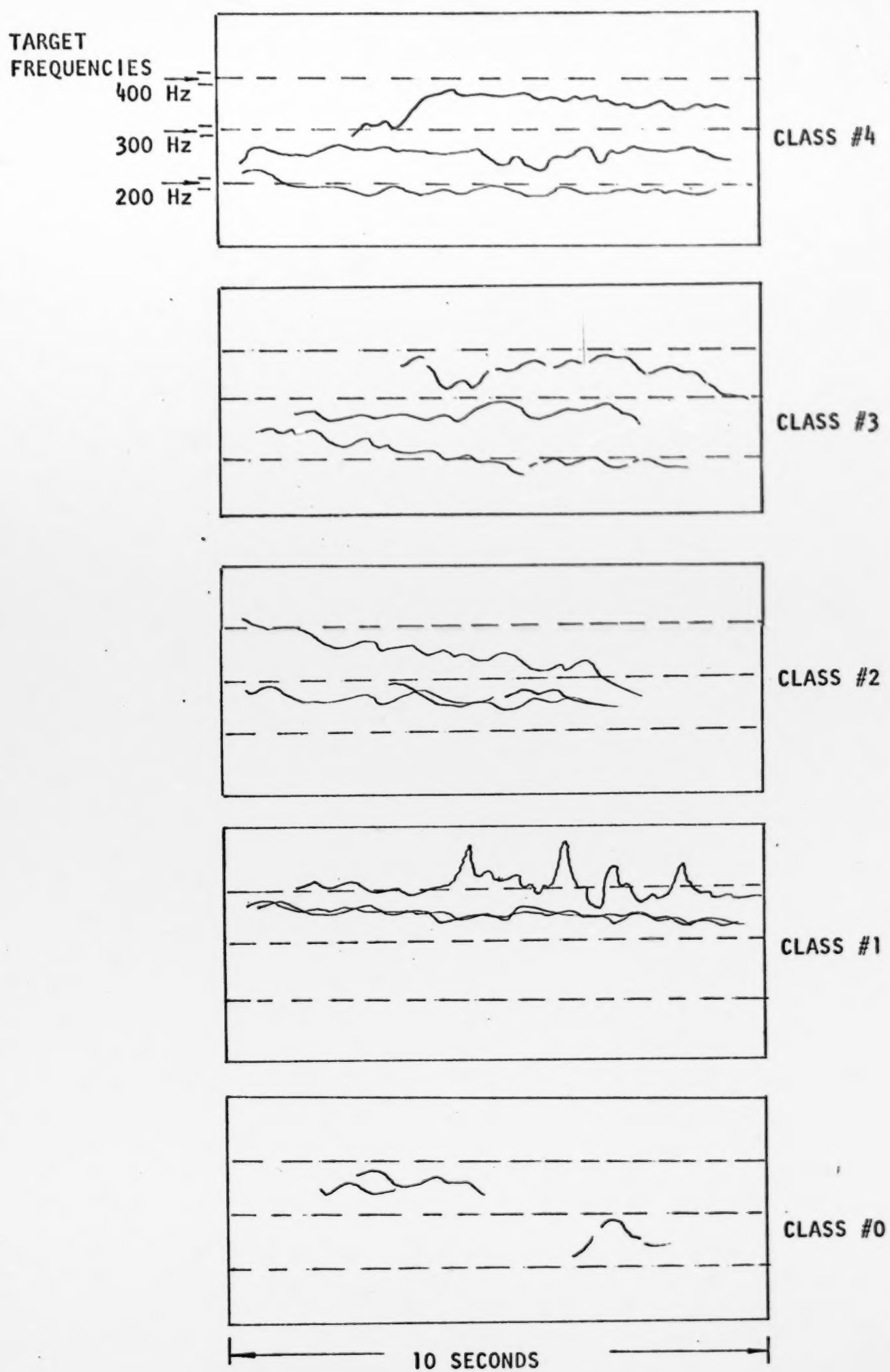


Fig.2. Pitch matching attempts illustrating the five classifications of performance.

on any differences of assessment. Such differences were, in fact, few.

Figure 2 shows tracings which were good examples of each class.

Results

1. Performance on the Pitch Matching Task

The number of students placed in each class is given in Table II, results being broken down into school divisions. It will be seen that performance on the task was generally very poor, only 37 of the 60 subjects showing some ability to control pitch.

Table II. Distribution of Subjects by School Division
and Performance on the Pitch Matching Task

Class Number.	Number of Subjects			Total
	Lower	Middle	Upper	
4	0	0	1	1
3	1	3	4	8
2	2	4	5	11
1	5	5	7	17
0	12	8	3	23

2. Pitch Control and Age

Computation of chi square showed that there were statistically significant differences of performance between the three school divisions, performance improving with age. Thus from lower to upper school there was a significant increase in the number of subjects scoring one or more, ($p < .01$) and two or more ($p < .05$). Cumulative frequency distributions for the three school divisions are shown in Figure 3.

3. Pitch Control and Sex

Since school division was a significant factor, and since only girls were used in the upper school group, the relation between performance on the pitch matching task and sex was investigated only in the two younger groups. Computation of chi square showed no significant difference between the performance of boys and girls.

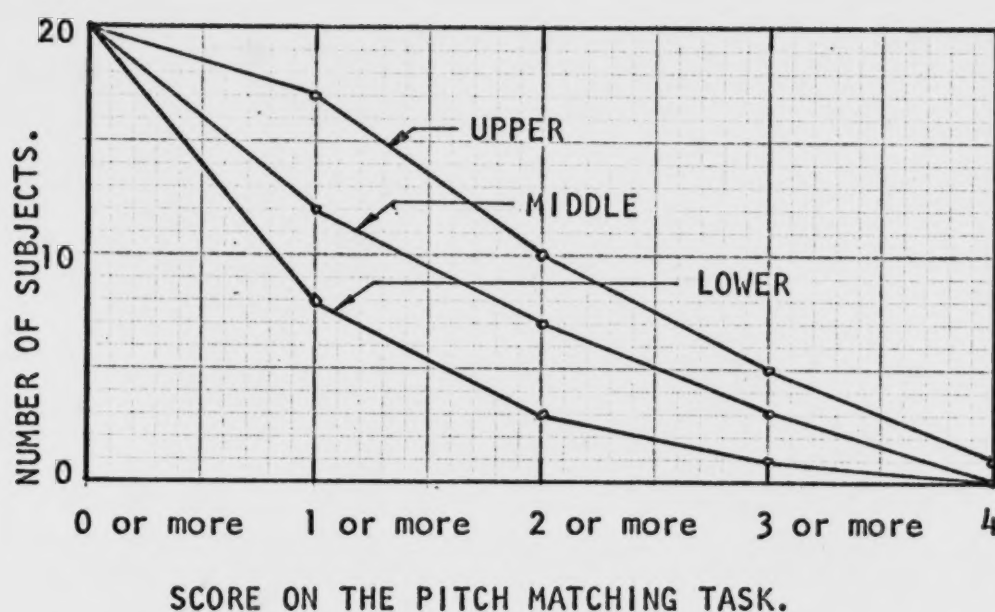


Fig. 3. Cumulative frequency distributions of scores on the pitch matching task for the subjects in the three school divisions.

4. Pitch Control and Habitual Pitch

The range of habitual pitch for the complete group was 180 Hz to 350 Hz with a mean of 266 Hz. There was a small but statistically significant difference ($p < .05$) between the means of the lower and middle school groups, as shown in Table III.

Table III. Habitual Pitch for the Subjects in the Three School Divisions

School Division	Mean Pitch in Hz	Sample Standard Deviation
Lower	276.25	24.33
Middle	252.25	43.83
Upper	270.75	41.00

Difference between lower and middle = 24.00 Hz, $t=2.09$, 38 d.f.

Difference between lower and upper = 5.50 Hz, $t=0.50$, 38 d.f.

Difference between middle and upper = 18.50 Hz, $t=1.34$, 38 d.f.

When the experimental group was divided into those with habitual pitch values of 250 Hz or less and those with values above 250 Hz, no evidence was found to show that these groups differed in performance on the pitch matching task.

5. Pitch Control and Hearing Loss

Subjects were divided into those with hearing losses at 125 Hz of 80 dB or less and those with losses greater than 80 dB. No evidence was found to indicate that these groups differed in performance on the pitch matching task. Similarly, division at 85 dB for 250 Hz, 95 dB for 500 Hz, 105 dB for 1000 Hz and 110 dB for 2000 Hz failed to indicate a significant relation between performance and hearing loss. Losses at 4000 and 8000 Hz were not included in view of the limited number of subjects responding at these frequencies.

6. Pitch Control and Intelligibility

As stated earlier, speech intelligibility scores were available for only middle and upper school children. The average score for the complete group was 34.4%. There was no evidence of a statistically significant difference between upper and middle school students. See Table IV.

Table IV. Mean Speech Intelligibility Scores for Upper and Middle School Groups

School Division	Mean Score %	Sample Standard Deviation
Upper	36.9	26.44
Middle	31.9	22.70

Difference=5% $t=0.63$, d.f. = 38

Computation of chi square showed that subjects with intelligibility scores below 30% did not perform significantly differently on the pitch matching task from the remaining subjects.

Discussion

The only factor significantly related to performance on the pitch matching task was school division. It seems most probable that this is due to the age,

maturity and speech experience of the older children, though other possibilities should be borne in mind. For instance, the intake of deaf children may have changed over the years with changing patterns of causation and increased availability of pre-school programs. Thus, there may be differences between children in the three school divisions other than those due to age and maturity.

If the improved pitch control is a feature of the educational exposure of these children, then it should be noted that this was accomplished without the aid of visible pitch displays.

The absence of a relation between pitch control and hearing loss may be attributed to the fact that all of the subjects were very severely or profoundly deaf. Had the experiment included some of the less deaf children in the school, an association between hearing loss and pitch control might have been more probable.

Perhaps the most interesting feature is the absence of a relation between pitch control and intelligibility. This rather suggests that emphasis might better be given to developing skills other than pitch control. However, there is an aspect of pitch control which was not examined in the present study, namely intonation. In addition, the device will lend itself to work on rhythm, which would be more likely to show a relation to intelligibility. Also, if it can be shown that the visible pitch device can achieve results in pitch control more rapidly than alternative methods, then it would make available more time for work on areas more directly related to intelligibility. These and other possibilities are being investigated as a continuation of this research.

Conclusions:

1. The overall performance on the pitch matching task was very poor.
2. There was a significant difference of performance between lower school and upper school subjects, the older children demonstrating better pitch control.
3. No evidence was found that performance on the pitch matching task was related to sex, hearing loss, habitual pitch, or speech intelligibility.

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